CLAIMS

1. A floor reaction force detection system of a legged mobile robot having at least a body and a plurality of legs each connected to the body through a first joint, and each having a foot connected to a distal end of the leg through a second joint, comprising:

(a) a displacement sensor installed at a position in or adjacent to an elastic member disposed between the second joint and a floor contact end of the foot, and generating an output indicating a displacement of the floor contact end of the foot relative to the second joint; and

(b) a floor reaction force calculator that calculates a floor reaction force acting on the foot based on the output of the displacement sensor, by using a model that describes a relationship between a displacement and a stress generated in the elastic member in response to the displacement of the floor contact end of the foot.

2. The system according to claim 1, wherein the model is described with a first spring, a dumper arranged in series with the first spring and a second spring arranged in parallel with the first spring and the dumper.

3. The system according to claim 2, wherein the floor reaction force calculator includes an observer that estimates the floor reaction force by estimating a displacement of the dumper.

4. The system according to any of claims 1 to 3, wherein the floor reaction force calculated by the floor reaction force calculator includes at least a force component acting in a direction of vertical axis.

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5. The system according to any of claims 1 to 4, wherein a plurality of the displacement sensors are disposed to be apart from each other when viewed from top and the floor reaction force calculator calculates the floor reaction force based on outputs of the displacement sensors.

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6. The system according to claim 5, wherein the floor reaction force calculated by the floor reaction force calculator includes a force component acting in a direction of vertical axis and a moment component acting about an axis that orthogonally intersects the vertical axis.

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7. The system according to any of claims 1 to 6, wherein the displacement sensor comprises a spring and a pressure-sensitivity sensor.

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8. The system according to claim 7, wherein a rigidity of the spring is set lower than that of the elastic member.

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9. The system according to any of claims 1 to 8, further including; .
a second floor reaction force detector installed at a position between the second joint and the floor contact end of the foot and generating an output indicating a floor reaction force acting on the foot from the floor surface which the robot contacts.

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10. The system according to claim 9, further including;

(c) a self-diagnoser that self-diagnoses whether abnormality or degradation occurs in at least one of the displacement sensor and the second floor reaction force detector based on the floor reaction force calculated by the floor reaction force calculator and the floor reaction force detected from the output of the second floor reaction force detector.

11. The system according to claim 10, wherein the self-diagnoser includes;

(d) a first determiner that determines whether at least one of a difference and a ratio between the floor reaction force calculated by the floor reaction force calculator and the floor reaction force detected from the output of the second floor reaction force detector is within a first predetermined range;

and self-diagnoses that at least one of the displacement sensor, the second floor reaction force detector and the elastic member degrades when it is determined that at least one of the difference and the ratio is not within the first determined range.

12. The system according to claim 10 or 11, wherein the self-diagnoser includes;

(e) a second determiner that determines whether at least one of a difference and a ratio between the floor reaction force calculated by the floor reaction force calculator and the floor reaction force detected from the output of the second floor reaction force detector is within a second predetermined range;

and self-diagnoses that the second floor reaction force detector is abnormal when it is determined that at least one of the difference and the ratio is not within the second predetermined range.

13. The system according to claim 11 or 12, wherein the self-diagnoser includes;

(f) a counter counting a number of times that at least one of the difference and the ratio is determined to be not within the first predetermined range;

and self-diagnoses that at least one of the displacement sensor, the second floor reaction force detector and the elastic member degrades when the counted number of times exceeds a predetermined number of times.

14. A floor reaction force detection system of a legged mobile robot having at least a body and a plurality of legs each connected to the body through a first joint, and each having a foot connected to a distal end of the leg through a second joint, comprising:

(a) a displacement sensor installed at a position in or adjacent to an elastic member disposed between the second joint and a floor contact end of the foot, and generating an output indicating a displacement of the floor contact end of the foot relative to the second joint;

(b) a floor reaction force detector installed at a position between the second joint and the floor contact end of the foot and generating an output indicating a floor reaction force acting on the foot from the floor surface which the robot contacts; and

(c) an adaptive observer that outputs a floor reaction force estimation error indicating a difference between a floor reaction forces estimated from the output of the displacement sensor and the floor reaction force detected from the output of the floor reaction force detector, using a model that describes a relationship between a displacement and a stress generated in the elastic member in response to the displacement of the floor contact end of the foot, and identifying a parameter value of the model.

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15. The system according to claim 14, further including;

(d) an elastic member self-diagnoser that self-diagnoses degradation of the elastic members based on at least the parameter value.

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16. The system according to claim 14 or 15, wherein the adaptive observer is separately installed for each foot.

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17. The system according to claim 14 or 15, wherein the adaptive observer is installed one for the feet.

18. The system according to claim 16, wherein the parameter value is used in

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the adaptive observers in common.

19. The system according to any of claims 14 to 18, further including;

(e) a floor reaction force detector self-diagnoser that self-diagnoses an

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abnormality of the floor reaction force detector based on the floor reaction force estimation errors.

20. The system according to any of claims 14 to 19, wherein the model is a

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model in which a viscoelastic characteristic of the elastic member is approximated by a spring and a dumper, and the parameter value is made of a constant of the spring and the dumper.